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TITLE

PANDORA MOTH STUDIES IN LODGEPOLE PINE ON THE ARAPAHO NATIONAL FOREST DURING 1938

By

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Assistant Entomologist

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Forest Insect Laboratory,
Fort Collins, Colorado
March 24, 1939

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Biology and Control of Pandora moth

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INTRODUCTION

During the middle of August 1937 an infestion of the pandora moth (Coloradia pandora Blake) was discovered in lodgepole pine on the Arapaho National Forest in central Colorado. Up to that time this insect was known chiefly as a pest of ponderosa pine in California and Oregon. General observations in the infestation during 1937 and description of the insect and habits have been reported upon by J. A. Beal*. No new centers of infestation have been found in addition to those reported upon. However, with the heavy flight of moths during 1938 the infested areas will be much larger unless natural factors limit the population. The larvae, which caused very little defoliation during 1938, are overwintering on the trees in the second and third instars. This coming season, 1939, will be the year of heavy defoliation.

The studies during the past season have been limited to occasional visits to the infestations during the summer because of the lack of sufficient personnel. Observations and collections were made by D. De Leon, C. L. Massey, and J. A. Beal during July and by D. Hester and N. D. Wygant during the remainder of the season. A more intensive study is planned for 1939.

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*Beal, J. A. A Pandora Moth Infestation in Lodgepole Pine in Western Colorado. March 16, 1938.

OBSERVATIONS AND STUDIES OF LIFE CYCLE

Adults.--The emergence of the moths started around the first of July and continued throughout the summer. The main emergence was during July and a few stragglers continued to appear in fewer numbers as the season advanced.

Upon emergence, the moths crawl up the trees before their wings have expanded. The male moths are attracted to the females and copulation may occur before the female moths are dry. Copulation usually occurs on the trunk of the tree with the head of the female pointed upward. The males are better fliers than the newly emerged females. This may be due to the fact that the abdomens of the females are heavily loaded with eggs. The early flight of the females consists of short distances as from the ground to the trees or from branch to branch. On July 8 in the center of an infestation there were 302 moths on a tree 8 inches in d.b.h. and 25 feet high. Of that total 80 moths were in the act of copulation, 176 were males, and 126 were females. When the area was visited again the first part of August the moths were not nearly as numerous as they were on July 8. Female moths with apparent vestigial wings were quite common. These moths mated and laid their eggs the same as the other moths, but no check was made on relative fertility of the eggs.

Numerous female moths were observed at the blue neon lights in the towns of Granby and Hot Sulphur Springs, Colorado on the evening of August 2. F. C. Craighead and J. A. Beal found numerous dead moths under the lights in Granby on July 28 that were attracted to the lights the previous evening. According to residents of these towns the moths

were even more numerous during the middle and the latter part of July. The storekeepers literally swept up bushels of the moths each morning that were killed at the lights the previous night. Occasionally there was a male moth among the female moths. It is possible but not probable that the male moths migrate with the female moths but are not attracted by the lights. The red, green, and white lights were not nearly as attractive as the blue. Granby is approximately 12 miles and Hot Sulphur Springs approximately 11 miles from the known infestations. It is possible that these moths came from unknown infestations nearer to the towns. The moths probably were migrating or in flight and were attracted to the lights when passing over the towns. One male moth was collected in a light trap at Rocky Ford, Colorado on August 3, 1938 by J. L. Hoerner. The specimen was badly battered and while it appears to be Coloradia sp. it is not definitely known that it is C. pandora. This locality is many miles from forests and it is not known from where the moth originated.

According to Patterson* in his studies with the pandora moth in southern Oregon and California, "The adults are strong fliers, and are strictly diurnal. In the writer's studies individuals could never be found active at night, nor could they be attracted to lights displayed in the forest after dark or before daylight." The moths in Granby were attracted almost entirely to the blue neon lights, with an

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*Patterson, J. E. The Pandora Moth. A Periodic Pest of Western Pine Forests. USDA Tech. Bul. 137, Oct. 1929.

occasional one attracted to bright white street lights. Patterson's failure to attract the moths to the lights was probably because he did not try blue lights or sufficiently bright lights.

The dead moths were counted under 3 trees in the center of an infestation on August 3 and found to be as follows:

Tree No.	Male	Female	Percent female
1	75	17	18
2	89	14	13
3	33	4	12

These data substantiate the evidence that the female moths are longer lived and migrate from the infestations. No counts have been made to determine the sex ratio but it is believed that the two sexes are about equal in number. The dead moths were concentrated on the southeast side of the trees, probably because of the prevailing northwest winds.

The moths had laid most of their eggs before making their flight to the lights. This condition is discussed under the topic, Eggs, that follows.

Eggs. The eggs develop in the females during the pupal stage and egg-laying may start the same day that the moth emerges. The newly laid eggs are light bluish green. As they become older they become bluish gray and are surprisingly difficult to see even on the bark of the trees. They are typically ovoid in shape and slightly

compressed on two opposite sides averaging 2.5 mm in length and 2 mm in width (figs. 1 and 2). The eggs are laid promiscuously on the bark or needles in groups of 1 to 50. In dense stands there are few eggs laid on the lower parts of the trees. In sparse stands the eggs are quite common on the trunk down to the ground line, but they were more concentrated towards the top.

The incubation period of the eggs was not accurately determined but it appeared to be approximately 40 days, the figure determined by Patterson. On August 3 no larvae had appeared but on August 26 approximately 50 percent of the eggs had hatched. On September 20 all the eggs had hatched on the south slopes but there were a few unhatched ones on the north exposures.

The average number of eggs in 27 females collected on July 8 that had not yet oviposited was 153.1. The average number of eggs in 50 females collected at a blue neon light in Granby, Colo., on August 2 was 19.7. The egg counts on the two groups of moths are summarized in the following table:

	No. Moths	Average No. Eggs	Greatest No. Eggs found in Moth	Smallest No. Eggs found in Moth
Moths not oviposited	27	153.1	187	109
Moths caught at light	50	19.7	97	0

Thirteen of the 50 moths caught at the light contained no eggs and this lowered the average per moth considerably. If 153.1 is considered the average number of eggs in a female that had not oviposited, the moths had laid 87 percent of their eggs before being attracted to the light.

Larvae.--The larvae started to hatch from the eggs during the first or second week in August and continued to hatch throughout the rest of the summer. By August 27 approximately 50 percent of the eggs had hatched. The larvae when they emerge from the eggs are black or brownish and covered with short dark hairs (figs. 2 and 3). The head is about 1.1 mm wide, and shiny black in color. The larvae are gregarious during the first instar but during the second instar seldom more than 3 or 4 larvae can be found in a group. The following table shows the percent of larvae in the instars at the time collections of larvae were made at random during the summer.

Date of Collection	Total Number Larvae	Percent in Instars 1	2	3
August 30	500	100		
September 20	307	88	12	
October 5	258	24	76	
November 10	179	3	93	4

At the time of the last collection, November 10, the larvae had discontinued activity for the winter. As shown by the table most of the larvae overwintered in the second instar. Larvae immediately became active when warmed up from the heat of a hand on November 10.

Head capsule measurements for the instars present during the past season were as follows:

Instar	No. Larvae Measured	Av. Width of Head in Inches	Variation in width
1	50	.0442	.041-.047
2	50	.0667	.063-.074
3	8	.0923	.089-.096

The various instars are distinguishable in the field without the use of a hand lens because of the relatively large size of the larvae.

Pupae.--Numerous pupae were found in the soil by Ranger D. O. Johnson in the infested area between Timber Creek and the East Fork of Troublesome Creek on October 14, 1938. He stated that in some places the live pupae probably would average 8 to 10 to the square foot. Several moths have emerged from the pupae he collected during the winter and sent to the laboratory at Ft. Collins. This means that there will be a flight of moths during 1939 and that two broods may be present in the infestation. Previous to the finding of the pupae only the one brood had been observed in the infestation. It

is not known whether these pupae are hold-overs from the ones that should have changed to adults during 1938 or whether they represent a distinct brood. Normally there is only the one brood present in an infestation and if this second brood appears in numbers equal to the first, the seriousness of the infestation will be greater because the trees will not have a year between each defoliation to recover. As yet no one from the Fort Collins office has had an opportunity to study the area where Ranger Johnson found the pupae.

Natural Enemies.--There has been very little opportunity to study the natural enemies of the pandora moth other than general observations in the infestation. Several thousand eggs were collected during the latter part of August for the rearing of egg parasites and not a single parasite was obtained from the lot. The eggs were placed in a cage in a warm room and only a small percent of the eggs hatched. It is also possible that conditions were not suitable for the development of the parasites. Fragments of eggs were found among feces of birds and a mammal; however, no animals were found actually feeding on the eggs.

No parasitization of the larvae was noticed. A few limp larvae were noted by D. De Leon on October 5 and it is possible that a wilt disease may be present.

It is hoped that the tachinid parasite Compsilura concinnata Meig. can be secured from the Forest Insect Laboratory at New Haven, Connecticut, for liberation in the infestation during this coming summer.

EXTENT OF INFESTATION

The largest known infestations occur on the drainages of Buffalo and East Fork of Troublesome Creeks. A lighter infestation occurs on Strawberry Ridge and between Meadow Creek and Trail Creek north of Tabernash. Although these are the only reported infestations, others no doubt occur. Because of the small amount of feeding of the larvae during their first summer, light infestations were difficult to detect during 1938. After the heavy feeding of the larvae during 1939 it should be more easy to detect new outbreaks. Dead moths were common in previously uninfested areas and they no doubt laid eggs over a very large area.

The aerial photographs of the Arapaho National Forest made by the U. S. Forest Service were studied to determine whether defoliated areas could be detected on them. The heavily defoliated areas on Buffalo and Timber Creeks could easily be detected. Other areas which appeared on the photographs to be infested were examined in the field and found to be covered with aspen or untimbered areas covered with sage brush. For this reason the aerial photographs were of little use in discovering new infestations.

SAMPLE PLOTS

During the last week of August and the first part of September a total of 6 sample plots were established in the infestation. Five of these were on the Buffalo Creek drainage and one between Timber

and East Fork Troublesome Creeks. The plots were established to study the effect of defoliation on the trees and succession of secondary insects in the trees weakened by the defoliation. The plots varied from 1/4 to 1 acre in size. As well as could be determined in the field they were located in areas representing somewhat different degrees of defoliation and stands of various density, tree sizes, and ages. Each tree was numbered with a metal tag and records taken of degree of defoliation, amount of new needle growth during 1938, vigor class, d.b.h., and estimated height. This data will be valuable in determining the fate of the trees in the various classes. Although this data is of little immediate value it has been analyzed to give a better picture of the conditions of the trees in the plots at this time (Tables I, II, III, IV, V).

Defoliation.--The degree of defoliation was arbitrarily divided into 5 classes: A--0 to 25 percent defoliation, B--25 to 50 percent, C--50 to 75 percent, D--75 to 90 percent, and E--90 to 100 percent. While it is very difficult to estimate accurately the degree of defoliation by merely looking at a tree it was hoped that sufficient accuracy was obtained to warrant the taking of the data. The degree of defoliation was judged by one individual so as to keep the estimates as uniform as possible. Frequent comparison of defoliated trees with uninfested trees was made to increase the accuracy. A photograph was taken of each plot to serve as an additional record as to the condition of the trees at the time of the establishment of the plots

(figs. 7-12 inclusive). Annual photographs taken of the plots to compare with the past photographs should aid in following the effects and degree of defoliation.

The data on the degree of defoliation are presented in Table I.

Table I

Plot No.	Total No. Trees	Percent of Trees in Defoliation Classes				
		A 0-25%	B 25-50%	C 50-75%	D 75-90%	E 90-100%
1	190	--	.5	5	46	48
2	798	5	27	49	16	3
3	365	13	31	13	17	26
4	344	5	2	26	65	7
5	154	--	73	20	2	--
6	68	--	--	5	7	88

The above table gives a general picture of the degree of defoliation in the 6 plots. Plots 1 and 6 were heavily defoliated, plots 2, 3, and 4 moderately, and 5 lightly defoliated. At the end of this coming season all of these trees should be checked again to determine the amount of defoliation received during this season.

New Needle Growth.--Because some of the trees defoliated in 1937 sent out new needles during the spring of 1938 and others did not, this condition was recorded for each tree at the same time that

the degree of defoliation was estimated. The amount of new growth was classified into one of the following groups: 1--new needle growth normal, 2--new needle growth short, 3--no needle growth or at most a few very short needles. This data is summarized in table II.

Table II

Plot	Trees with Needle Growth During 1938		
	1 Normal	2 Poor	3 Practically none
1	13	93	84
2	287	408	103
3	171	83	111
4	51	277	16
5	151	3	0
6	2	5	61

The trees with the least defoliation naturally put forth better needle growth during 1938 than the trees with heavy defoliation. Most of the trees that were completely defoliated during 1937 made no needle growth during 1938.

Vigor Class.--Each tree was classified according to Taylor's* tree classification for lodgepole pine in Colorado and Wyoming to determine the effect of defoliation upon the trees in each vigor class. The percentage of trees falling into each vigor class on each plot is given in table III.

*Taylor, R. F. A Tree Classification for Lodgepole Pine in Colorado and Wyoming. Jour. For. vol. XXXV, no. 9, pp. 868-875. 1937.

Table III

Plot No.	No. Trees	Area of Plot in Acres	Percent of Trees in Vigor Class A	B	C	D
1	190	1.0	7.4	21	52	20
2	798	1.0	.1	2	15	83
3	365	1.0	.5	6	58	36
4	344	.5	1.5	5	72	22
5	154	1.0	3.9	10	66	20
6	68	.25	0	9	81	10

Plot No. 2 had a large percentage of D trees because of the very dense stand.

Diameter Class.--Every tree on the plots was measured at breast height with a diameter tape. Table IV shows the number of trees in each diameter class.

Table IV

Plot No.	Number of Trees in Diameter Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	9	16	13	19	21	13	12	13	14	21	18	9	4	5	2		1
2	49	151	161	127	125	90	55	26	7	6	1						
3	3	4	16	24	27	40	51	55	51	49	13	23	1	6	1		1
4	30	56	87	68	50	25	13	9	4	1	1						
5	2	2	2		3	6	6	11	19	14	25	21	11	13	13	4	2
6	1	2		1	5	7	8	17	12	5	8	3		1			

Plots 2 and 4 had trees of smaller diameter and denser stocking. Plot 5 had the largest trees. The other plots were more typical of the area.

Height Class.--The height of each tree was estimated to the nearest 5-foot interval. A Forest Service hypsometer was used to check on the estimated height at frequent intervals. The number of trees in each height class is given in Table V.

Table V

Plot No.	Height Classes in Feet													
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
1		4	15	18	24	28	21	27	21	20	6	5	1		
2	1	4	26	78	123	176	170	125	53	32	8	2			
3			1	2	7	7	9	26	71	97	80	44	18	3	
4		3	38	63	98	85	40	26	10	1					
5		2	1			1	2	6	4	25	28	55	15	13	2
6		1		1	1	1		11	20	30	3				

Increment.--Ten increment cores were taken from the more vigorous trees on each plot. The annual growth was measured for the past 20 years and averaged for each plot. It was thought that years of defoliation could be dated by a sudden decline in growth, but such did not prove to be the case. Growth during 1938, the year following heavy defoliation, was nearly the same as during the previous 4 or 5 years. It is possible that the trees failed to make an annual ring during 1938. The annual increment on lodgepole pine was so small that it was impossible

to measure and to date the rings by comparison. In fact on many cores it was impossible to see the annual rings without staining the cores and there is a chance that some of the annual rings were not counted. A small area of phloem, about 1 inch square, was removed from each of the trees from which the cores were taken to determine whether the trees fail to make an annual ring during 1939. The future annual rings can also be dated from the scar.

The trees on plots 1, 2, 3, 5, and 6 were even aged, approximately 100 years old. The trees on plot 4 varied from 34 to 72 years old. The latter plot appeared to be on the edge of an old burn and the younger trees came in after the burn. The trees on the area as a whole are even-aged and are probably in the 100-year class.

General Notes on Plots

Plot 1

Plot size 1 acre square

Plot on ridge running east and west with about 1/3 of plot on top of ridge, 1/3 on south aspect, and 1/3 on north aspect.

Soil gravelly with sandy loam

Reproduction--small amount

Duff shallow

Trees bored for increment cores Sept. 1938: 2, 14, 32, 39, 78, 93, 115, 121, 168, 174

Photograph taken 25 feet N. of S.E. corner of plot toward N.W. corner

Plot 2 (General notes on plot 2 to be obtained spring of 1939)

Plot 3

Plot size 1 acre square

Plot on ridge running east and west. Heaviest defoliation on south side of plot and lightest on north side.

Soil gravel with sandy loam

Reproduction sparse

Duff shallow

Trees bored for increment cores September 1938: 1019, 1037, 1039, 1062, 1158, 1160, 1161, 1224, 1225, 1272

Photograph taken half-way between trees 1160 and 1158 toward northeast.

Plot 4

Plot size 1/2 acre

Plot on southeast slope between Timber Creek and East Fork Troublesome

Soil coarse gravel mixed with sandy loam, rock outcrops.

Reproduction sparse

Duff shallow

Trees bored for increment cores September 1938: 1446, 1431, 1515, 1518, 1522, 1591, 1635, 1698, 1700, 1704

Photograph taken 8 feet south of tree 1430 toward the west

Plot 5

Plot size 1 acre square

Plot on eastern aspect

Soil sandy loam with no rock outcrops

Reproduction 6 inches to 3 feet high and good

Duff medium

Trees bored for increment cores were 1729, 1789, 1747, 1771, 1809, 1810, 1813, 1829, 1852, and 1857

Photograph taken from corner 4 toward corner 2

Plot 6

Plot size 1/4 acre square

Plot on northeast aspect

Soil gravelly loam. No rock outcrops

Reproduction sparse

Duff medium deep

Trees bored for increment cores were 1872, 1885, 1889, 1891, 1899, 1901, 1902, 1908, 1909, 1937

Photograph taken from corner 3 toward corner 1

SUMMARY

The first infestation of the pandora moth ever reported in lodgepole pine was discovered on the Arapaho National Forest in central Colorado during August 1937. Since that time general observations and a few limited studies have been made in the area.

The moths started to emerge around the first of July and continued throughout the summer, but the heavy emergence was during July. Very soon after emergence mating and egg laying started. The early flights of the moths were from the ground to a tree or from branch to branch. Later the moths made long distance flights as indicated by the large number of female moths attracted to the blue neon lights in Granby and Hot Sulphur Springs, Colorado, during July and August. Nearly all of the moths attracted to the lights were females. The average number of eggs in these moths was 19.7 as compared to 153.1 eggs in females that had just emerged. The eggs develop in the pupae and are laid by the moths promiscuously on the trunks of trees, branches, and needles in groups of 1 to 50. The eggs hatch in about 40 days. During the first instar the larvae feed gregariously but lose this habit in the later instars. Most of the larvae are wintering in the second instar with a few in the first and third on the branches. The average widths of the heads of the first three instars found during the summer were .0442, .0667, and .0923 inch respectively.

Numerous live pupae were found in the soil in the infestation between Timber and East Fork of Troublesome Creeks on October 14, 1938, by Ranger Johnson. This may mean that there will be a flight of moths during 1939 and that two broods may be present in the infestation. It is not known whether these pupae are hold-overs from the ones that

should have changed to adults during 1938 or whether they represent a distinct brood.

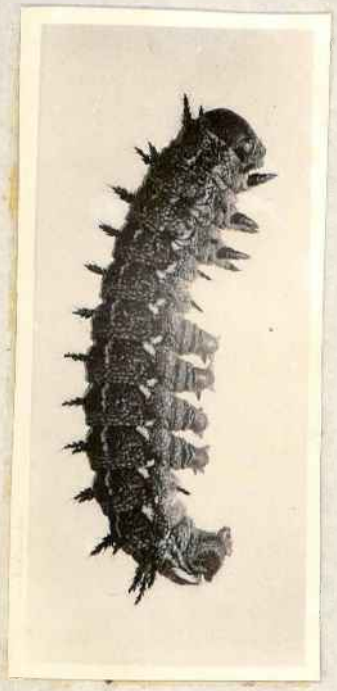
No large new infestations have been found during the past season. With the expected extensive feeding during 1939, new areas will probably be discovered. A study of aerial photographs made of the Arapaho National Forest during the summer of 1937 revealed that while heavily defoliated areas could be located, aspen stands and sage brush appeared similar to defoliated areas and therefore the aerial photographs were of little use in discovering new infestations.

During the last of August and first of September a total of 6 sample plots were established in the infestations to study the effect of defoliation on the trees and the succession of secondary insects in the trees weakened by the defoliation. The plots varied in size from 1/4 to 1 acre and were established in areas representing different degrees of defoliation and stands of various density, tree sizes and ages. These plots are to be studied each succeeding year to follow the fate of the infestation. Each tree was numbered with a metal tag and records taken of degree of defoliation, amount of new needle growth, vigor class, d.b.h., and estimated height. Increment cores were taken from 10 trees in each plot and the annual growth analyzed for the past 20 years. The growth data failed to show any sudden decrease in increment as expected soon after defoliation. The annual growth is very small on lodgepole pine and the failure of the increment study may have been due to the inability to see all annual rings.

a

b

Fig. 1. Pandora moth eggs. a-terminal shoot showing egg clusters ½ X. b-egg cluster 2 X.



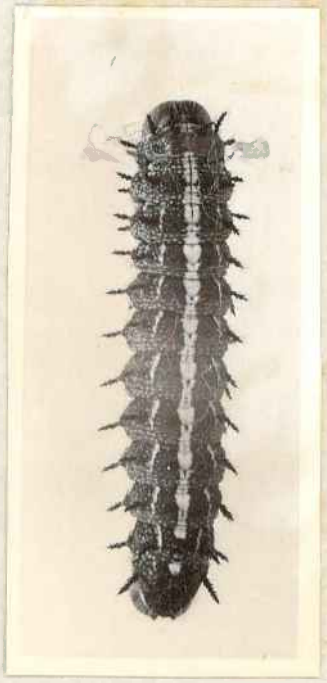
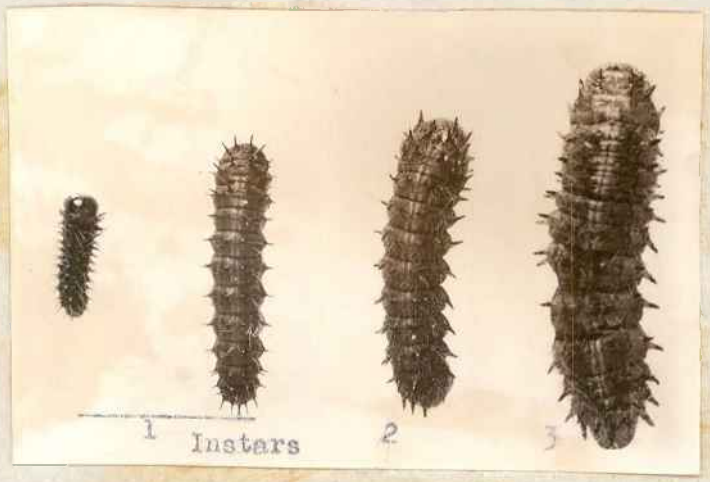


Fig. 2. Lateral and dorsal view of larva in 5th instar 2 X.



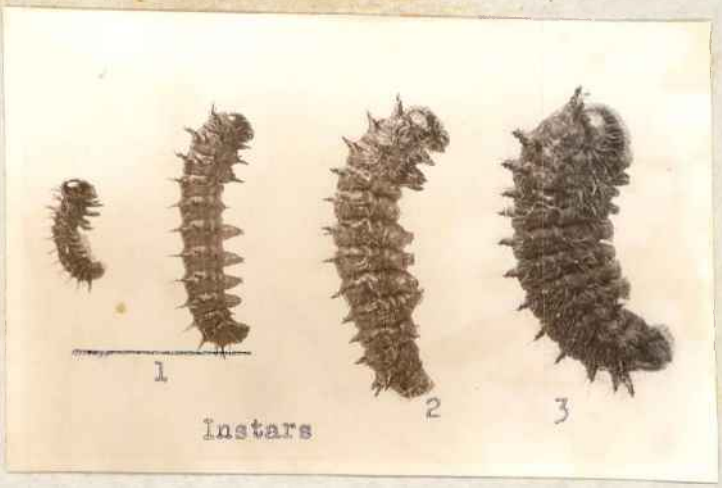


Fig. 3. Dorsal and lateral views of larvae in first three instars, 3½ X.

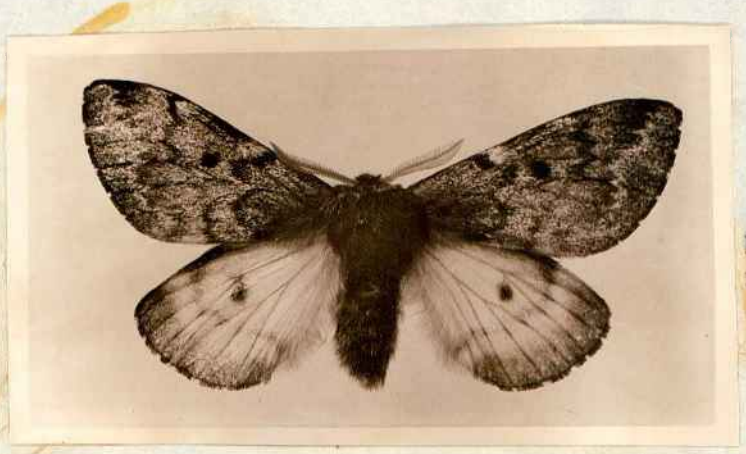


Fig. 4.
Male moth
natural size

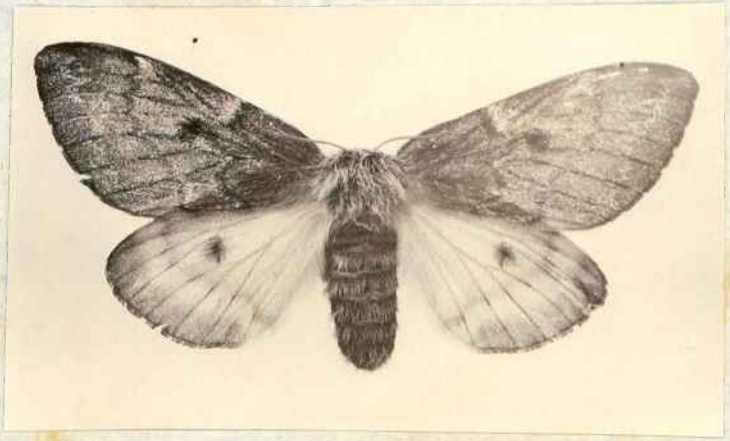


Fig. 5.
Female moth
natural size

Fig. 6.
Pupae in earthen
cells X 3/4

Fig. 7. Plot 1. Photograph taken 25 feet north of southeast corner of plot looking toward northwest corner.

Fig. 8. Plot 2.

Fig. 9. Plot 3. Photograph taken halfway between trees 1160 and 1158 looking toward northeast.

Fig. 10. Plot 4. Photograph taken 8 feet south of tree 1430 looking toward the west.

Fig. 11.
Plot 5.
Photograph
taken from
corner 4
looking
toward
corner 2.

Fig. 12.
Plot 6.
Photograph
taken from
corner 3
looking
toward
corner 1.